Emergency Exemption for Transform® WG Insecticide (sulfoxaflor) to control the tarnished plant bug, *Lygus lineolaris*, in cotton.

Type of Emergency Exemption for Louisiana: specific exemption under FIFRA Section 18; April 20, 2016.

This is an application for a specific exemption to authorize the use of Sulfoxaflor (Transform® WG Insecticide) to control the tarnished plant bug, *Lygus lineolaris*, in cotton. The following information is submitted in the format indicated in the proposed rules for Chapter 1, Title 40 CFR, Part 166.

SECTION 166.20(a)(1): IDENTITY OF CONTACT PERSONS

i. **The following contact persons are available to answer regulatory questions regarding the Section 18 emergency exemption:**

Name: Scotty May
Title: Program Coordinator, Pesticide & Environmental Programs Division
Organization: Louisiana Department of Agriculture and Forestry
Address: 5825 Florida Blvd., Suite 3003, Baton Rouge, LA 70806
Telephone Number: (225) 925-3789
Email: amay@ldaf.state.la.us

Name: Kevin Wofford
Title: Director, Pesticide & Environmental Programs Division
Organization: Louisiana Department of Agriculture and Forestry
Address: 5825 Florida Blvd., Suite 3003, Baton Rouge, LA 70806
Telephone Number: (225) 925-3763
Email: kwofford@ldaf.state.la.us

Name: Harry Schexnayder
Title: Assistant Director, Pesticide & Environmental Programs Division
Organization: Louisiana Department of Agriculture and Forestry
Address: 5825 Florida Blvd., Suite 3003, Baton Rouge, LA 70806
Telephone Number: (225) 925-3768
Email: hschexnayder@ldaf.state.la.us

ii. The following qualified experts are also available to answer questions:

University Representative:

Name: David Kerns
Title: Associate Professor Entomology
Department: Macon Ridge Research Station
Organization: LSU AgCenter
Address: 212A Macon Ridge Road, Winnsboro, LA 71295
Telephone Number: (318) 435-2157
E-mail: DKerns@agcenter.lsu.edu

Registrant Representative:

Name: Tami Jones-Jefferson
Title: U.S. Regulatory Leader
Organization: Dow AgroSciences
Address: 9330 Zionsville Road, Indianapolis, IN 46268
Telephone Number: (317) 337-3574
E-mail: tjjonesjefferson@dow.com

SECTION 166.20(a)(2): DESCRIPTION OF THE PESTICIDE REQUESTED

i. Common Chemical Name (Active Ingredient): Sulfoxaflor

Brand/Trade Name and EPA Reg. No.: Transform® WG Insecticide, the registration is currently cancelled (Attachment 3)

Formulation: Active Ingredient 50%

SECTION 166.20(a)(3): DESCRIPTION OF THE PROPOSED USE

i. Sites to be Treated:
Cotton fields infested with the tarnished plant bug, *Lygus lineolaris*, located statewide are proposed to be treated.

ii. Method of Application:
Applications will be made by foliar sprays by aircraft and/or ground equipment.

iii. **Rate of Application:**
1.5 - 2.25 oz Transform WG/acre (0.047 - 0.071 lb ai/acre)

iv. **Maximum Number of Applications:**
4 applications per year (maximum of 8.5 oz/acre (0.266 lb ai/acre)

v. **Total Acreage to be Treated:**
For the 2016 growing season, Dr. David Kerns estimated that the acreage planted in cotton should not exceed 160,000 acres (4 applications = 640,000 treated acres) in Louisiana.

vi. **Total Amount of Pesticide to be Used:**
If the maximum amount of estimated cotton acreage is treated for tarnished plant bug infestation (100% infestation of 160,000 acres) at the maximum rate for the year at 8.5 oz/acre (0.266 lb ai/acre), then 85,000 lbs of Transform WG or 42,500 lbs of active ingredient would be used for the 2016 growing season.

vii. **Restrictions and Requirements:**

- Pre-harvest Interval: Do not apply within 14 days of harvest.
- Minimum Treatment Interval: Do not make applications less than 5 days apart.
- Do not make more than four applications per acre per year.
- Do not make more than two consecutive applications per crop.
- Do not apply more than a total of 8.5 oz of Transform WG (0.266 lb ai of sulfoxaflor) per acre per year.
- Label must include a pollinator advisory statement including but not limited to the following:
    - Notifying known beekeepers within 1 mile of the treatment area 48hours before the product is applied will allow them to take additional steps to protect bees.
    - If known apiaries are within one mile of cotton fields intended for treatment, applications should be made within three hours of sunset during the flowering period.
    - Prior to use of Transform WG, growers and the beekeepers hosted on their farm are advised to implement cooperative standards outlined in the Louisiana Pollinator Cooperative Conservation Program.
- Transform WG can be used once the tarnished plant bug population reaches the recognized Louisiana action threshold of 2-3 tarnished plant bugs per 5 feet black drop cloth, 10 tarnished plant bugs per 100 sweep net samples or 10% dirty squares (published in Louisiana Pest Management Guide, Pub 1838).

viii. **Duration of the Proposed Use:**
May 15 – October 31, 2016

ix. **Earliest Possible Harvest Date:**
September 15, 2016

SECTION 166.20(a)(4): ALTERNATIVE METHODS OF CONTROL

Alternative Insecticides

Presently a number of insecticides are included in Louisiana's recommendations for strategies for controlling tarnished plant bug in cotton. Other than the section 3 registration of sulfoxaflor in 2013, there have been no new insecticide active ingredients labelled in cotton for tarnished plant bug management. Over the past eight years (2008-2016) a robust data set including 88 trials in 13 locations has been generated demonstrating the efficacy of sulfoxaflor and alternative insecticide products for managing tarnished plant bug in Louisiana. These trials illustrate the performance of a large number of insecticides to tarnished plant bug over a wide range of environmental conditions and tarnished plant bug infestation levels.

Many of the products currently available are used as single applications and as single applications, they are not effective but require follow-up applications within 5 days. Cook et al. (2007) showed that standard insecticide use strategies can reduce tarnished plant bug numbers, but none are consistently effective and can maintain sub-economic injury levels for the season. The results in Figure 1 illustrate that reliance on a single class of chemistry (exceptions were the IGR novaluron [Diamond] and Endigo) was not effective in maintaining tarnished plant bug populations below the action threshold (line marked with AT) used to gauge the need for additional treatments to stop yield losses. Six sprays were applied to this Louisiana trial which was designed to simulate moderate to high pest infestation levels, typical of the situation in many Louisiana and Mid-South cotton fields (Figure 1, Sharp et al. 2010 and B. R. Leonard unpublished). Using seasonal means of tarnished plant bug nymphs as a metric for insecticide efficacy, all treatments significantly reduced numbers relative to a non-treated control. However, inability to manage below these levels for the entire season suggests that yield losses are likely.

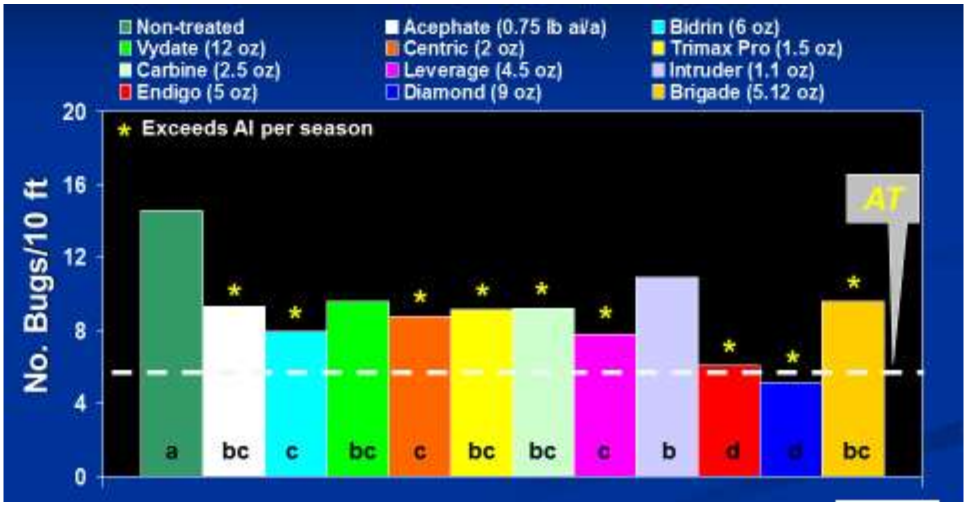

Figure 1. Efficacy of insecticides against tarnished plant bug nymphs - 2009.

In addition, all of the bars highlighted with an asterisk (*) illustrate that six applications of those treatments exceeded the total allowable seasonal AI/acre. Only Vydate and Intruder AI's were not exceeded. <u>The key point from these data suggests that with none of these products are effective based upon currently accepted IPM principles relying on action thresholds and adherence to insecticide label restrictions.</u>

Insecticide resistance is a contributing factor to the lack of satisfactory performance with most recommended insecticides and has been documented to nearly every class of these compounds among Mid-South (Arkansas, <u>Louisiana,</u> Mississippi, and Tennessee) populations of this insect. Populations have demonstrated resistance to pyrethroids and some organophosphates for several years (Snodgrass and Gore 2007), but many populations remained susceptible to neonicotinoids including thiamethoxam and imidacloprid (Snodgrass et al. 2008). Acephate had been the most widely used and effective insecticide for control of plant bugs in cotton, but efficacy continues to decrease in Louisiana and across the Mid-South. Three years of field work by Copes et al. (2010) clearly shows that acephate efficacy has rapidly eroded across Louisiana (Figure 2).

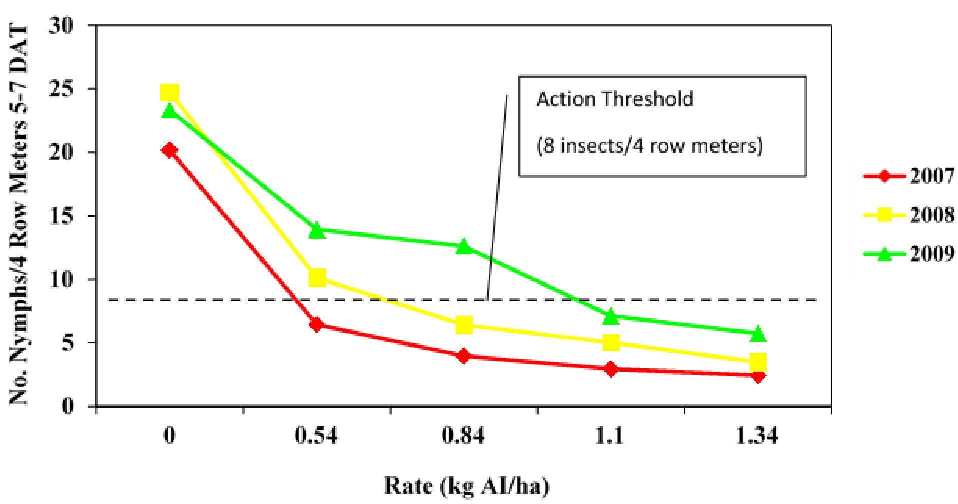

Figure 2. A three year summary (2007-2009) of acephate efficacy against the tarnished plant bug in Louisiana field trials. The line indicates the action threshold of eight tarnished plant bugs / four row meters.

Even though acephate expressed partial efficacy against tarnished plant bugs in Louisiana, higher rates (0.5 to 1.25 lb-AI/acre) have been necessary each year from 2007 to maintain the infestations below the action threshold. The highest rate actually exceeded the labeled rate that could be used. Recent (Adams et al. 2012) work from Mississippi further illustrated the weakness of acephate at high rates (1.0 lb-AI/acre) in controlling tarnished plant bug. Field efficacy results are supported by laboratory data from Snodgrass and others showing significant levels of OP resistance in tarnished plant bug populations throughout the Mid-South states including Louisiana.

Similar to Copes et al. (2010) work with Orthene as a candidate OP, field trials were initiated in 2010 and continued in 2011 for the neonicotinoids using thiamethoxam (Centric) in Figure 3. The mean results of three trials showed that only the highest labeled rate was effective in reducing populations below the action threshold (AT represented by the dashed line on graph). These field results are further supported by Snodgrass laboratory bioassays. During the past several years, Mid-South populations of tarnished plant bugs have demonstrated reduced susceptibility to neonicotinoid products **(**Snodgrass and Gore 2007, Emfinger et al. 2014). During 2015, Centric at 2.0 oz per acre was ineffective towards Louisiana tarnished plant bugs even after two applications, relative to Transform at 1.5 or 2.0 oz/acre which provided acceptable control (Figure 4).

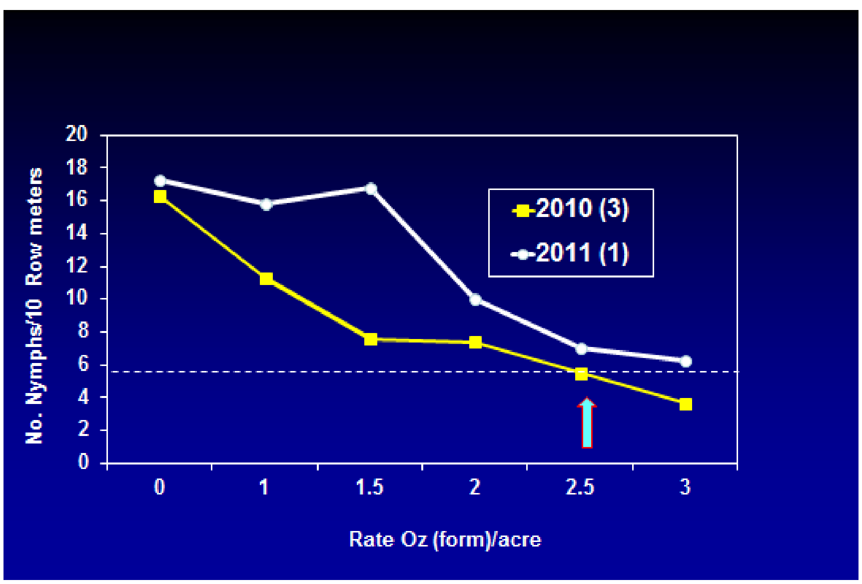

Figure 3. Thiamethoxam (Centric) Efficacy as Rate Responses Against Native Infestations of Tarnished Plant Bug In 2010-11(total n=4) Louisiana Cotton Field Trials. The dashed line indicates the action threshold for treatment initiation and suggests the highest labeled rate (2.5 oz) provides marginal or ineffective control.

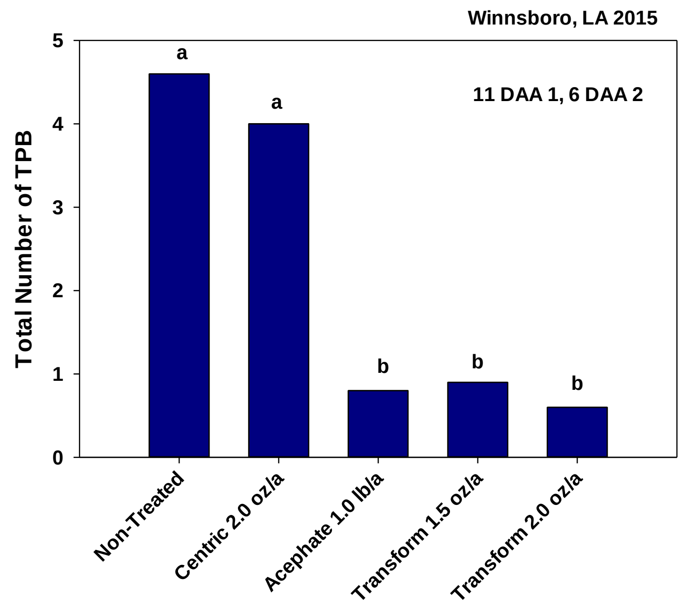

Figure 4. Efficacy of insecticides targeting tarnished plant bugs in Louisiana, 2015.

Organophosphates and neonicotinoids are the primary chemistry used to control Louisiana tarnished plant bug. Pyrethroids are poor-performing products and resistance to these insects has been documented for a number of years in Louisiana. In 1995, plant bug populations highly resistant to the pyrethroid class of insecticides were found in MS, and this resistance quickly spread throughout the delta of AR, LA, and MS. Pyrethroid insecticides are no longer recommended for the control of tarnished plant bugs in cotton across this region (Figure 5). Use of these products usually results in tarnished plant bug populations higher than in the non-treated. Novaluron (Diamond) an IGR, is only effective against nymphs and allows the adult stage of the insects to cause significant injury and severe yield loss. The performance of flonicamid (carbine) is inconsistent and has not provided effective control against heavy infestations. Finally, the best strategy is the use of co-applications of products such as pyrethroids + OP's or pyrethroids + neonicotinoids. However, in recent years even these mixes have proven ineffective (Figure 6).

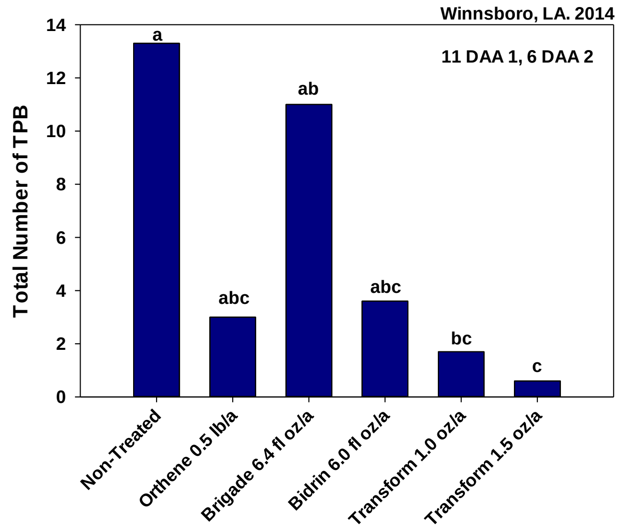

Figure 5. Effectiveness of commonly used insecticides towards TPB after 2 applications in Louisiana in 2014.

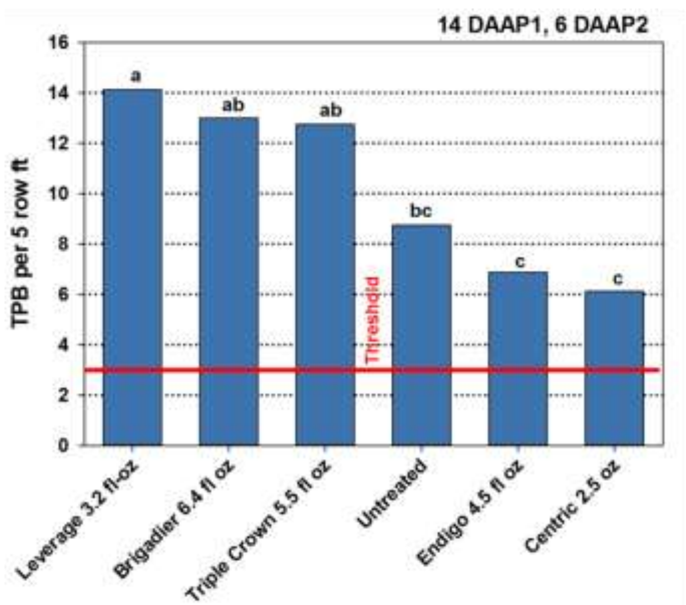

Figure 6. Effectiveness of neonicotinoids mixed with pyrethroids towards TPB after 2 applications in Louisiana in 2013.

Another problem we are encountering is that the total AI per acre per season of these products is not sufficient to provide season-long control. Regardless of the registered insecticide, tarnished plant bug populations in Louisiana have become significantly more difficult to control using recommended products (Lorenz et al. 2009, Moore et al. 2010, Emfinger et. al 2014). As a result, the insecticide application frequencies combined with actual use rates have reached the upper limits. In spite of this maximum use of products, yield losses in some areas have exceeded 20%. Effective Lygus control is a serious, unmet need for Louisiana cotton growers and one that requires immediate and urgent action. With the recent loss in the section 3 registration of Transform, we are now facing an emergency situation.

SECTION 166.20(a)(5): EFFICACY OF USE PROPOSED UNDER SECTION 18

Results across a large composite of tests and conditions showed that Transform was equal to or better than the standard products in providing immediate knockdown, residual toxicity, yield protection, and activity against populations expressing resistance to other insecticide classes (Willrich Siebert et al. 2012a,b). Independent trials in Louisiana confirmed the value of this product against native populations of this pest in Tensas Parish, Louisiana. Tensas is one of the regions of the Louisiana that has consistently high and persistent tarnished plant bug infestations during July and August. This region has an environment similar to the Delta counties in Western Mississippi. Results in Table 1 show a significant yield increase with Transform above the commercial standards included in a 2010 field trial. These data show yields from a field trial where four applications of the treatments were made in an overall tarnished plant bug management program. Results of a second test (performed in 2011) are presented in Table 2. This test only included two applications (adverse weather conditions prohibited additional sprays). These data are more variable, but consistently illustrate the performance of sulfoxaflor relative to other insecticide treatments. These results show that even though the recommended insecticides significantly impact tarnished plant bug infestations and increase cotton yields above the non-treated control, severe losses (>20%) in yield still can occur in some areas of Louisiana. Alternative insecticide treatments do provide some measure of control, however; economic injury and yield loss with these recommended treatments was considered excessive during the past several years and is likely to increase.

Table 1. Impact of tarnished plant bug management in cotton with different classes of insecticides on cotton yields in 2010, Tensas parish, Louisiana.

Treatment	Rate (lb AI/acre)	Total TPB Adults + Nymphs (Total No./Plot)[1]	Nymphs (Season Mean- N=7 samples)[1]	Yield (lb lint/A)[1]	Percent Yield increase[2]	Percent Yield increase[3]
Sulfoxaflor	0.067	14.7 c	1.6 c	1105.0 a	49.0	21.9
Bidrin	0.4	28.8 b	3.5 bc	909.2 b	23.2	----
Brigade	0.08	39.7 b	4.7 b	869.7 bc	17.9	----
Non-treated	---	64.3 a	7.4 a	737.9 c	----	----

[1]Means followed by the same letter are not significantly different (P<0.05).
[2]The percent yield increase above the non-treated control.
[3]The percent yield increase of sulfoxaflor above the highest yielding insecticide (Bidrin).

Table 2. Impact of tarnished plant bug management in cotton with different classes of insecticides on cotton yields in 2011, Tensas parish, Louisiana.								
Treatment		**Rate (lb AI/acre)**		**Total TPB Adults + Nymphs (Total No./Plot)[1]**	**Nymphs (Season Mean- N=8 samples)[1]**	**Yield (lb lint/A)[1]**	**% Yield increase[2]**	**% Yield increase[3]**
Sulfoxaflor		0.047		29.3 b	3.7 b	714.1a	64.7	22.5
Bidrin		0.5		37.3 b	4.2 b	582.8ab	34.4	----
Acephate + Diamond		0.75 + 0.039		35.0 b	4.1 b	569.2ab	31.3	----
Non-treated		---		73.8 a	8.8 a	433.5 b	----	----

[1]Means followed by the same letter are not significantly different ($P<0.05$).
[2]The percent yield increase above the non-treated control.
[3]The percent yield increase of sulfoxaflor above the highest-yielding insecticide (Bidrin).

In laboratory studies, the effectiveness of sulfoxaflor against insecticide-susceptible populations of tarnished plant bug was comparable to those of other labeled classes of insecticides. <u>However, it is more important that sulfoxaflor-induced mortality was similar between insecticide-resistant and susceptible strains of several Homoptera and Heteroptera</u> (Babcock et al. 2010, Zhu et al. 2011). No cross-resistance was detected to sulfoxaflor in populations expressing resistance to a broad range of modes of action. In those areas of Louisiana experiencing persistent high populations of tarnished plant plants, use of the available products in the currently recommended chemical control strategies is not economically feasible, sustainable, or environmentally friendly.

SECTION 166.20(a)(6): EXPECTED RESIDUES FOR FOOD USES

There should not be any residue levels in food since the product is not being applied to food crops.

SECTION 166.20(a)(7): DISCUSSION OF RISK INFORMATION

Human Health

<u>Toxicological Profile</u>
Sulfoxaflor is a member of a new class of insecticides, the sulfoximines. It is an activator of the nicotinic acetylcholine receptor (nAChR) in insects and, to a lesser degree, mammals.

The nervous system and liver are the target organs, resulting in developmental toxicity and hepatotoxicity.

Developmental toxicity was observed in rats only. Sulfoxaflor produced skeletal abnormalities likely resulting from skeletal muscle contraction due to activation of the skeletal muscle nAChR in utero. Contraction of the diaphragm, also related to skeletal muscle nAChR activation, prevented normal breathing in neonates and increased mortality. The skeletal abnormalities occurred at high doses while decreased neonatal survival occurred at slightly lower levels.

Sulfoxaflor and its major metabolites produced liver weight and enzyme changes, and tumors in subchronic, chronic and short-term studies. Hepatotoxicity occurred at lower doses in long-term studies compared to short-term studies.

Reproductive effects included an increase in Leydig cell tumors which were not treatment related due to the lack of dose response, the lack of statistical significance for the combined tumors, and the high background rates for this tumor type in F344 rats. The primary effects on male reproductive organs are secondary to the loss of normal testicular function due to the size of the Leydig Cell adenomas. The secondary effects to the male reproductive organs are also not treatment related. It appears that rats are uniquely sensitive to these developmental effects and are unlikely to be relevant to humans.

Clinical indications of neurotoxicity were observed at the highest dose tested in the acute neurotoxicity study in rats. Decreased motor activity was also observed in the mid- and high-dose groups. Since the neurotoxicity was observed only at a very high dose and many of the effects are not consistent with the perturbation of the nicotinic receptor system, it is unlikely that these effects are due to activation of the nAChR.

Tumors have been observed in rat and mouse studies. In rats, there were significant increases in hepatocellular adenomas in the high-dose males. In mice, there were significant increases in hepatocellular adenomas and carcinomas in high dose males. In female mice, there was an increase in carcinomas at the high dose. Liver tumors in mice were treatment-related. Leydig cell tumors were also observed in the high-dose group of male rats, but were not related to treatment. There was also a significant increase in preputial gland tumors in male rats in the high-dose group. Given that the liver tumors are produced by a non-linear mechanism, the Leydig cell tumors were not treatment-related, and the preputial gland tumors only occurred at the high dose in one sex of one species, the evidence of carcinogenicity was weak.

<u>Ecological Toxicity</u>
Sulfoxaflor (N-[methyloxido[1-[6-(trifluoromethyl)-3-pyridinyl]ethyl]-lambda 4-sulfanylidene]) is a new variety of insecticide as a member of the sulfoxamine subclass of neonicotinoid insecticides. It is considered an agonist of the nicotinic acetylcholine receptor and exhibits excitatory responses including tremors, followed by paralysis and mortality in target insects. Sulfoxaflor consists of two diastereomers in a ratio of approximately 50:50 with each diastereomer consisting of two enantiomers. Sulfoxaflor is systemically distributed in plants when applied. The chemical acts through both contact action and

ingestion and provides both rapid knockdown (symptoms are typically observed within 1-2 hours of application) and residual control (generally provides from 7 to 21 days of residual control). Incident reports submitted to EPA since approximately 1994 have been tracked via the Incident Data System. Over the 2012 growing season, a Section 18 emergency use was granted for application of sulfoxaflor to cotton in four states (MS, LA, AR, TN). No incident reports have been received in association with the use of sulfoxaflor in this situation.

Sulfoxaflor is classified as practically non-toxic on an acute exposure basis, with 96-h LC_{50} values of >400 mg a.i./L for all three freshwater fish species tested (bluegill, rainbow trout, and common carp). Mortality was 5% or less at the highest test treatments in each of these studies. Treatment-related sublethal effects included discoloration at the highest treatment concentration (100% of fish at 400 mg a.i./L for bluegill) and fish swimming on the bottom (1 fish at 400 mg a.i./L for rainbow trout). No other treatment-related sublethal effects were reported. For an estuarine/marine sheepshead minnow, sulfoxaflor was also practically non-toxic with an LC_{50} of 288 mg a.i./L. Sublethal effects included loss of equilibrium or lying on the bottom of aquaria at 200 and 400 mg a.i./L. The primary degradate of sulfoxaflor is also classified as practically non-toxic to rainbow trout on an acute exposure basis (96-h LC_{50} >500 mg a.i./L).

Adverse effects from chronic exposure to sulfoxaflor were examined with two fish species (fathead minnow and sheepshead minnow) during early life stage toxicity tests. For fathead minnow, the 30-d NOAEC is 5 mg a.i./L based on a 30% reduction in mean fish weight relative to controls at the next highest concentration (LOAEC=10 mg a.i./L). No statistically significant and/or treatment-related effects were reported for hatching success, fry survival and length. For sheepshead minnow, the 30-d NOAEC is 1.3 mg a.i./L based on a statistically significant reduction in mean length (3% relative to controls) at 2.5 mg a.i./L. No statistically significant and/or treatment-related effects were reported for hatching success, fry survival and mean weight.

The acute toxicity of sulfoxaflor was evaluated for one freshwater invertebrate species, the water flea and two saltwater species (mysid shrimp and Eastern oyster). For the water flea, the 48-h EC_{50} is >400 mg a.i./L, the highest concentration tested. For Eastern oyster, new shell growth was significantly reduced at 120 mg a.i./L (75% reduction relative to control). The 96-h EC_{50} for shell growth is 93 mg a.i./L. No mortality occurred at any test concentration. Mysid shrimp are the most acutely sensitive invertebrate species tested with sulfoxaflor based on water column only exposures, with a 96-h LC_{50} of 0.67 mg a.i./L. The primary degradate of sulfoxaflor is also classified as practically non-toxic to the water flea (EC_{50} >240 mg a.i./L).

The chronic effects of sulfoxaflor to the water flea were determined in a semi-static system over a period of 21 days to nominal concentrations of 6.25, 12.5, 25, 50 and 100 mg a.i./L. Adult mortality, reproduction rate (number of young), length of the surviving adults, and days to first brood were used to determine the toxicity endpoints. No treatment-related effects on adult mortality or adult length were observed. The reproduction rate and days to first brood were significantly ($p<0.05$) different in the 100 mg a.i./L test group (40% reduction in mean number of offspring; 35% increase in time to first brood). No significant effects were observed on survival, growth or reproduction at the lower test concentrations. The 21-day NOAEC and LOAEC were determined to be 50 and 100 mg a.i./L, respectively.

The chronic effects of sulfoxaflor to mysid shrimp were determined in a flow-through system over a period of 28 days to nominal concentrations of 0.063, 0.13, 0.25, 0.50 and 1.0 mg a.i./L. Mortality of parent (F_0) and first generation (F_1), reproduction rate of F_0 (number of young), length of the surviving F_0 and F_1, and days to first brood by F_0 were used to determine the toxicity endpoints. Complete F_0 mortality (100%) was observed at the highest test concentration of 1.0 mg a.i./L within 7 days; no treatment-related effects on F_0/F_1 mortality, F_0 reproduction rate, or F_0/F_1 length were observed at the lower test concentrations. The 28-day NOAEC and LOAEC were determined to be 0.11 mg and 0.25 mg a.i./L, respectively.

Sulfoxaflor exhibited relatively low toxicity to aquatic non-vascular plants. The most sensitive aquatic nonvascular plant is the freshwater diatom with a 96-h EC_{50} of 81.2 mg a.i./L. Similarly, sulfoxaflor was not toxic to the freshwater vascular aquatic plant, *Lemna gibba*, up to the limit amount, as indicated by a 7-d EC_{50} for frond count, dry weight and growth rate of >100 mg a.i./L with no significant adverse effects on these endpoints observed at any treatment concentration.

Based on an acute oral LD_{50} of 676 mg a.i./kg bw for bobwhite quail, sulfoxaflor is considered slightly toxic to birds on an acute oral exposure basis. On a subacute, dietary exposure basis, sulfoxaflor is classified as practically nontoxic to birds, with 5-d LC_{50} values of >5620 mg/kg-diet for mallard ducks and bobwhite quail. The NOAEL from these studies is 5620 mg/kg-diet as no treatment related mortality of sublethal effects were observed at any treatment. Similarly, the primary degradate is classified as practically nontoxic to birds on an acute oral exposure basis with a LD_{50} of >2250 mg a.i./kg bw. In two chronic, avian reproductive toxicity studies, the 20-week NOAELs ranged from 200 mg/kg-diet (mallard, highest concentration tested) to 1000 mg/kg-diet (bobwhite quail, highest concentration tested). No treatment-related adverse effects were observed at any test treatment in these studies.

For bees, sulfoxaflor is classified as very highly toxic with acute oral and contact LD_{50} values of 0.05 and 0.13 μg a.i./bee, respectively, for adult honey bees. For larvae, a 7-d oral LD_{50} of >0.2 μg a.i./bee was determined (45% mortality occurred at the highest treatment of 0.2 μg a.i./bee). The primary metabolite of sulfoxaflor is practically non-toxic to the honey bee. This lack of toxicity is consistent with the cyano-substituted neonicotinoids where similar cleavage of the cyanide group appears to eliminate their insecticidal activity. The acute oral toxicity of sulfoxaflor to adult bumble bees (*Bombus terrestris*) is similar to the honey bee; whereas its acute contact toxicity is about 20X less toxic for the bumble bee. Sulfoxaflor did not demonstrate substantial residual toxicity to honey bees exposed via treated and aged alfalfa (i.e., mortality was <15% at maximum application rates).

At the application rates used (3-67% of US maximum), the direct effects of sulfoxaflor on adult forager bee mortality, flight activity and the occurrence of behavioral abnormalities is relatively short-lived, lasting 3 days or less. Direct effects are considered those that result directly from interception of spray droplets or dermal contact with foliar residues. The direct effect of sulfoxaflor on these measures at the maximum application rate in the US is presently not known. When compared to control hives, the effect of sulfoxaflor on honey bee colony strength when applied at 3-32% of the US maximum proposed rate was not apparent in most cases. When compared to hives prior to pesticide application, sulfoxaflor applied to cotton foliage up to the maximum rate proposed in the US resulted in no discernible decline in mean colony strength by 17 days after the first application. Longer-term results were not available from this study nor were concurrent controls included. For managed bees, the primary exposure routes of concern include direct contact with spray droplets, dermal contact with foliar residues, and ingestion through consumption of contaminated pollen, nectar and associated processed food provisions. Exposure of hive bees via contaminated wax is also possible. Exposure of bees through contaminated drinking water is not expected to be nearly as important as exposure through direct contact or pollen and nectar.

In summary, sulfoxaflor is slightly toxic to practically non-toxic to fish and freshwater water aquatic invertebrates on an acute exposure basis. It is also practically non-toxic to aquatic plants (vascular and non-vascular). Sulfoxaflor is highly toxic to saltwater invertebrates on an acute exposure basis. The high toxicity of sulfoxaflor to mysid shrimp and benthic aquatic insects relative to the water flea is consistent with the toxicity profile of other insecticides with similar MOAs. For birds and mammals, sulfoxaflor is classified as moderately toxic to practically non-toxic on an acute exposure basis. The threshold for chronic toxicity (NOAEL) to birds is 200 ppm and that for mammals is 100 ppm in the diet. Sulfoxaflor did not exhibit deleterious effects to terrestrial plants at or above its proposed maximum application rates.

For bees, sulfoxaflor is classified as very highly toxic. However, if this insecticide is strictly used as directed on the Section 18 supplemental label, no significant adverse effects are expected to Louisiana wildlife. Of course, standard precautions to avoid drift and runoff to waterways of the state are warranted. As stated on the Section 18 label, risk to managed bees and native pollinators from contact with pesticide spray or residues can be minimized when applications are made before 7 am or after 7 pm or when the temperature is below 55˚F at the site of application.

Environmental Fate

Sulfoxaflor is a systemic insecticide which displays translaminar movement when applied to foliage. Movement of sulfoxaflor within the plant follows the direction of water transport within the plant (i.e., xylem mobile) as indicated by phosphor translocation studies in several plants. Sulfoxaflor is characterized by a water solubility ranging from 550 to 1,380 ppm. Sulfoxaflor has a low potential for volatilization from dry and wet surfaces (vapor pressure= 1.9×10^{-8} torr and Henry's Law constant= 1.2×10^{-11} atm m^3 $mole^{-1}$, respectively at 25 °C). Partitioning coefficient of sulfoxaflor from octanol to water (K_{ow} @ 20 C & pH 7= 6; Log K_{ow} = 0.802) suggests low potential for bioaccumulation. No fish bioconcentration study was provided due to the low K_{ow}, but sulfoxaflor is not expected to bioaccumulate in aquatic systems. Furthermore, sulfoxaflor is not expected to partition into the sediment due to low K_{oc} (7-74 mL/g).

Registrants tests indicate that hydrolysis, and both aqueous and soil photolysis are not expected to be important in sulfoxaflor dissipation in the natural environment. In a hydrolysis study, the parent was shown to be stable in acidic/neutral/alkaline sterilized aqueous buffered solutions (pH values of 5, 7 and 9). In addition, parent chemical as well as its major degradate, were shown to degrade relatively slowly by aqueous photolysis in sterile and natural pond water ($t^{½}$= 261 to >1,000 days). Furthermore, sulfoxaflor was stable to photolysis on soil surfaces. Sulfoxaflor is expected to biodegrade rapidly in aerobic soil (half-lives <1 day). Under aerobic aquatic conditions, biodegradation proceeded at a more moderate rate with half-lives ranging from 37 to 88 days. Under anaerobic soil conditions, the parent compound was metabolized with half-lives of 113 to 120 days while under anaerobic aquatic conditions the chemical was more persistent with half-lives of 103 to 382 days. In contrast to its short-lived parent, the major degradate is expected to be more persistent than its parent in aerobic/anaerobic aquatic systems and some aerobic soils. In other soils, less persistence is expected due to mineralization to CO_2 or the formation of other minor degradates.

In field studies, sulfoxaflor has shown similar vulnerability to aerobic bio-degradation in nine out of ten terrestrial field dissipation studies on bare-ground/cropped plots (half-lives were <2 days in nine cropped/bare soils in CA, FL, ND, ON and TX and was 8 days in one bare ground soil in TX). The chemical can be characterized by very high to high mobility (Kf_{oc} ranged from 11-72 mL g^{-1}). Rapid soil degradation is expected to limit chemical amounts that may potentially leach and contaminate ground water. Contamination of groundwater by sulfoxaflor will only be expected when excessive rain occurs within a short period (few days) of multiple applications in vulnerable sandy soils. Contamination of surface water by sulfoxaflor is expected to be mainly related to drift and very little due to run-off. This is because drifted sulfoxaflor that reaches aquatic systems is expected to persist while that reaching the soil system is expected to degrade quickly with slight chance for it to run-off.

When sulfoxaflor is applied foliarly on growing crops it is intercepted by the crop canopy. Data presented above appear to indicate that sulfoxaflor enters the plant and is incorporated in the plant foliage with only limited degradation. It appears that this is the main source of the insecticide sulfoxaflor that would kill sap sucking insects. This is because washed-off sulfoxaflor, that reaches the soil system, is expected to degrade.

In summary, sulfoxaflor has a low potential for volatilization from dry and wet surfaces. This chemical is characterized by a relatively higher water solubility. Partitioning coefficient of sulfoxaflor from octanol to water suggests low potential for bioaccumulation in aquatic organisms such as fish. Sulfoxaflor is resistant to hydrolysis and photolysis but transforms quickly in soils. In contrast, sulfoxaflor reaching aquatic systems by drift is expected to degrade rather slowly. Partitioning of sulfoxaflor to air is not expected to be important due to the low vapor pressure and Henry's Law constant for sulfoxaflor. Exposure in surface water results from the drifted parent compound, and only minor amounts are expected to run-off only when rainfall and/or irrigation immediately follow application. The use of this insecticide is not expected to adversely impact Louisiana ecosystems when used according to the Section 18 label. Of course, caution is needed to prevent exposure to water systems because of toxicity issues to aquatic invertebrates. In the environmental hazards section on the label, the following statements are included: "Do not apply directly to water, to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment washwaters." As outlined in the spray drift management section on the Section 18 label, guidelines are included on the label to reduce off target drift including topics such as wind, temperature inversions, and droplet size. The label states that "Risk of exposure to sensitive aquatic areas can be reduced by avoiding applications when wind directions are toward the aquatic area."

Endangered and Threatened Species in Louisiana
No impacts are expected on endangered and threatened species by this very limited use of this insecticide as delineated in the Section 18 application. Sulfoxaflor demonstrates a very favorable ecotoxicity and fate profile as stated above and should not directly impact any protected mammal, fish, avian, or plant species. This product does adversely affect insects and aquatic invertebrates, especially bees, but the limited exposure to these species should not negatively affect endangered and threatened species in Louisiana when applications follow the label precautions.

A list of endangered and threatened species is included (Attachment 4).

The above content in Section 166.20(a)(7): Discussion of Risk Information was, for the most part, prepared by Michael Hare, Ph.D. (Human Health Effects), David Villarreal, Ph.D. (Ecological Effects), and David Villarreal, Ph.D. (Environmental Fate), all with the Texas Department of Agriculture. The parts of the above content in this section, with references to Louisiana, were prepared by LDAF.

SECTION 166.20(a)(8): COORDINATION WITH OTHER AFFECTED STATE OR FEDERAL AGENCIES

The following state/federal agencies were notified of the Louisiana Department of Agriculture and Forestry's (LDAF) actions to submit an application for a specific exemption to EPA:

- Louisiana Department of Environmental Quality (LDEQ) Water Quality
- Louisiana Department of Wildlife and Fisheries (LDWF)
- U.S. Fish and Wildlife Department

Responses from these agencies will be forwarded to EPA immediately if and when received by LDAF.

SECTION 166.20(a)(9): ACKNOWLEDGEMENT BY THE REGISTRANT

Dow AgroSciences has been notified of this agency's intent regarding this application and have offered a letter of support (Attachment 2). They have also provided a copy of the proposed Section 18 label with the use directions for this use although this use is dependent upon approval by EPA (Attachment 3).

SECTION 166.20(a)(10): DESCRIPTION OF PROPOSED ENFORCEMENT PROGRAM

LDAF has state statutory authority to regulate the distribution, storage, sale, use and disposal of pesticides in the state of Louisiana. LDAF will ensure proper use of the product and accurate reporting of the use information.

A final report will be submitted to EPA after the 2016 growing season for which the Section 18 specific exemption is requested. Field enforcement staff at LDAF, as appropriate, will monitor sales of Transform® WG Insecticide, make use observations, and respond to misuse complaints.

SECTION 166.20(a)(11): REPEAT USES

The LDAF applied for a specific exemption for this use in 2011, and the specific exemption request was withdrawn. In 2012 the LDAF requested for a specific exemption for this use, and the request was authorized by the EPA.

SECTION 166.20(b)(1): NAME OF THE PEST

Common Name: tarnished plant bug

Scientific Name: *Lygus lineolaris*

SECTION 166.20(b)(2): DISCUSSION OF EVENTS OR CIRCUMSTANCES WHICH BROUGHT ABOUT THE EMERGENCY SITUATION

Over the past 5 years, based on the USDA National Agricultural Statistics Service, Louisiana averaged approximately 185,000 acres. Principle parishes producing cotton in Louisiana include Avoyelles, Bossier, Caddo, Caldwell, Catahoula, Concordia, DeSoto, East Carroll, Evangeline, Franklin, Grant, LaSalle, Madison, Morehouse, Natchitoches, Ouachita, Pointe Coupee, Rapides, Red River, Richland, St. Landry, Tensas, West Baton Rouge, and West Carroll. Any cotton field within the state of Louisiana is susceptible to excessive infestations of tarnished plant bugs (> 2-3 action thresholds and direct yield losses > 20%) and outbreaks of this pest (Figure 7).

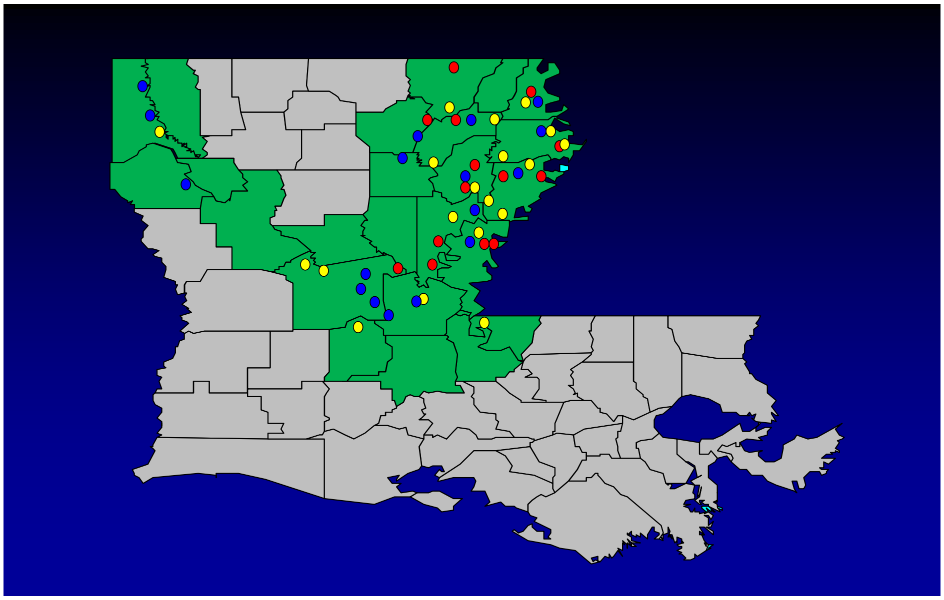

Figure 7. Cotton production parishes in Louisiana (in green) and reports (by private agricultural consultants) of tarnished plant bug chemical control failures prior to the introduction of sulfoxaflor (2009-11) years (dots w/in parishes).

Louisiana has experienced a dramatic reduction in cotton acreage, >40% over the past 4 years (Table 3). The primary driver in this shift in acreage reflects lower cotton commodity prices relative to alternative commodities. Since 2011, most of Louisiana's cotton acreage has shifted to areas where tarnished plant bugs, *Lygus lineolaris* (Palisot de Beauvois), are more prevalent. This shift has resulted in slight greater insecticide applications, losses due to tarnished plant bugs and plant bug related expenses (Table 3).

In 2016 mild winter conditions and available soil moisture have provided plentiful resources to support tarnished plant bug pest population development. Therefore, the potential for earlier infestations in cotton and higher numbers, at sustained levels, is a strong possibility during the 2016 production period. This observation should be coupled with the fact that a reduction in more than 40% of Louisiana cotton acreage since 2008 will serve to concentrate infestations on less area causing even more control problems.

In addition, there are several key points that have evolved over a period of time which are linked to the emergency condition which has occurred with yield and economic losses from tarnished plant bug in Louisiana. These issues have been ongoing for a number of years and have caused unusual and uncommon circumstances for this pest. The consequence of Southern production system changes is that tarnished plant bug has become the dominant season-long pest across this region during the last decade. Higher populations which persist longer during the season, control costs and crop losses associated with tarnished plant bugs have increased dramatically. There are two general categories of issues; those that have contributed to higher population levels by changes in the farmscape and those which have affected insecticide efficacy.

Factors Affecting Tarnished Plant Bug Populations

1. A reduction in broad spectrum insecticide efficacy from boll weevil sprays in the early 1990's, the termination of the state's boll weevil eradication program, adoption of transgenic Bt cotton (eliminated caterpillar sprays) and registration of highly target- specific insecticides (little to no activity against tarnished plant bug).
2. During the last decade, the tarnished plant bug has evolved to using native hosts and other crop for population development during the summer season and increasing those numbers available to move into cotton. Population development has been recently documented on a spring grass host (rye grass on field borders), pig weed (*Amaranthus spp*.) and mares tail (horseweed). There are populations of these specific weedy plants that now express multi-factorial resistance to herbicides. These plants can contribute to insect development both within and around cotton fields.
3. The increase in crop land removed from production and placed into Conservation Reserve (CRP) and Wetlands Reserve Programs (WRP) during the last decade has provided a non-insecticide treated refuge for tarnished plant bug population development and migration into cotton. These CRP/WRP areas are randomly distributed throughout Louisiana and produce numerous spring/summer host plants for this insect. There can be no host management strategies applied to these areas.
4. Tarnished plant bugs are using field corn and soybean early in the year as transitional hosts before migrating into cotton. The farmscape is much more balanced on Louisiana farms with consistent production of all three crops in adjacent fields or on nearby farms. The effects of this pest at the interface of cotton and other crops is devastating (Figure 8) to cotton yield and nearly uncontrollable.

Figure 8. Season-long Effects of Tarnished Plant Bug Immigration Into Cotton at the Interface of a Corn Field. Corn stubble is evident on the right side of the cotton field.

SECTION 166.20(b)(3): DISCUSSION OF ANTICIPATED RISKS TO ENDANGERED OR THREATENED SPECIES, BENIFICIAL ORGANISMS, OR THE ENVIRONMENT REMEDIED BY THE PROPOSED USE

As expected, the excessive use of some products for tarnished plant bug often results in the induction of secondary pest outbreaks, primarily spider mites and cotton aphids. This is of great concern to many producers and pest management practitioners. Organophosphate, carbamate and pyrethroid insecticides can impact natural beneficial arthropod populations and flare secondary insects such as aphids and spider mites.

Since the introduction of sulfoxaflor in Louisiana cotton, there have been a number of benefits in Louisiana IPM and a reduction in secondary pest outbreaks. This reduction results from cross-pest activity and reduced impact on insect predators (Lindsay et al. 2014). In bioassays, in Louisiana, sulfoxaflor resulted in 33% mortality when lady beetles were directly exposed (Figure 9). Mortality was negligible when sulfoxaflor leaf residue was dry (Figure 10). The relatively low impact sulfoxalfor exhibits on predaceous insects makes it highly desirable for inclusion into IPM programs. <u>Since its introduction in Louisiana cotton, losses due to cotton aphids has declined more than 67%.</u>

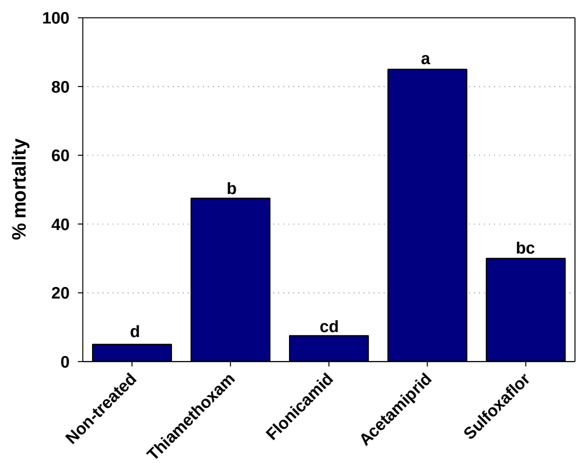

Figure 9. Mortality of lady beetle larvae directly exposed to normal use rates of cotton insecticides.

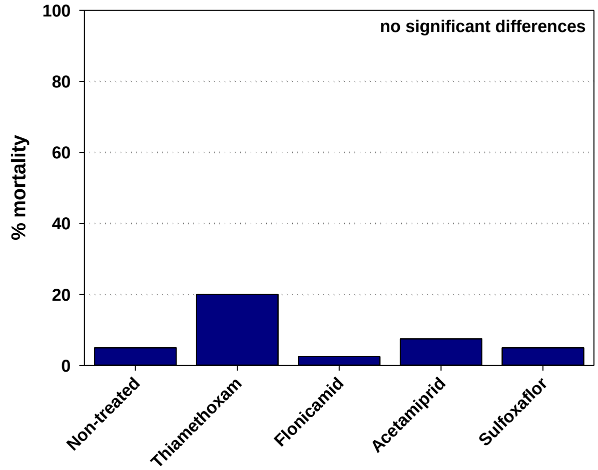

Figure 10. Mortality of lady beetle larvae indirectly exposed to normal use rates of cotton insecticides.

Pollinator Protection Provisions
Louisiana has an active pollinator protection program, Louisiana Pollinator Cooperative Conservation Program (LPCCP), http://www.lsuagcenter.com/portals/communications/publications/publications_catalog/environment/bees/cooperative-standards-adopted-by-louisiana-pollinator-cooperative-conservation-program . The mission of the LPCCP is to foster cooperation among bee keepers, pesticide applicators and agricultural producers for the purpose of preventing honey bees and pollinators from the unreasonable exposure to pesticides through education and stewardship recommendations in the state of Louisiana. An additional step to protect pollinators during emergency use of sulfoxaflor in cotton will be to restrict the application of sulfoxaflor to within 3 hours of sunset where managed honey bee hives are within 1.0 mile of the target field during bloom.

SECTION 166.20(b)(4): DISCUSSION OF SIGNIFICANT ECONOMIC LOSS

Tier 1 Criterion Justification
Prior to the introduction of sulfoxaflor into cotton as a section 18 registration in 2012 or a section 3 registration beginning in 2013, informal surveys of private agricultural consultants working in Louisiana cotton fields indicated that about 33% (80,850 acres) of the 2012 planted acreage would meet the criteria of >20% yield losses. This is due to tarnished plant bug in spite of using multiple and season-long applications of recommended insecticides for this pest. Following the introduction of sulfoxaflor in 2014, less than 2% (< 3,000 acres) experienced > 20% yield losses associated with tarnished plant bug injury, and these acres suffered loss due to inability of producers to make timely insecticide applications. Despite the shift of acreage into areas more prone to high tarnished plant bug infestation since the introduction of sulfoxaflor, Louisiana has experienced a **39.95% increase in yield** relative to the 4-years prior to sulfoxaflor introduction (Table 3). This value clearly shows a highly significant benefit to Louisiana cotton growers when sulfoxaflor is available for managing

tarnished plant bugs. This almost doubles the required 20% increase requested for emergency use justification.

Table 3. Tier one analysis of emergency situation (pre –introduction of sulfoxaflor) compared to non-emergency (post introduction of sulfoxaflor) for tarnished plant bug in Louisiana cotton.

Year	Cotton Acreage[1]	% acreage treated for TPB[2]	Average no. applications targeting TPB[2]	Average cost ($) per application[2]	Total cost ($/ac)	Percent yield loss[2]	Average yield per acre[1]
Prior to introduction of sulfoxaflor							
2008	300,000	98.6	2.7	15.42	41.63	3.56	576
2009	230,000	84.2	3.8	12.70	48.26	2.14	745
2010	255,000	97.6	3.1	15.68	48.61	4.10	842
2011	295,000	93.6	4.0	13.88	55.52	4.76	846
Averages	**270,000**	**93.5**	**3.40**	**14.42**	**48.51**	**3.64**	**752.25**
Post introduction of sulfoxaflor							
2012	230,000	100	4.0	14.63	58.52	3.00	1,020
2013	130,000	100	3.0	14.00	42.00	3.00	1,223
2014	170,000	100	4.0	16.00	64.00	5.00	1,154
2015	115,000	100	4.0	16.00	64.00	5.00	814
Averages	**161,250**	**100**	**3.75**	**15.16**	**57.13**	**4.00**	**1052.75**
Percent change (pre-sulfoxaflor vs. post sulfoxaflor)							
	-40.28%	**+6.50%**	**+10.29%**	**+5.13%**	**+17.77%**	**+9.89%**	**+39.95%**

[1]USDA National Agricultural Statistics Service, http://www.nass.usda.gov/Statistics_by_State/Louisiana/
[2]Cotton Insect Losses, http://entomology.msstate.edu/resourcs/cottoncrop.asp.

Tier 2 Criterion Justification

Since introduction of sulfoxaflor in Louisiana cotton, the cost of controlling tarnished plant bugs in Louisiana have increased 17.76% (Table 4). This increase in cost represents inflation and the fact that a higher percentage of Louisiana cotton is now grown in high plant bug population areas. In addition to increasing control costs, the average price of cotton is 7.46% lower since the introduction of sulfoxaflor relative to the previous 4 years. Despite, higher control costs and lower crop values **Gross Revenue has increased 26.27%** during this same time period. This value clearly shows a significant economic benefit to Louisiana cotton growers when sulfoxaflor is available for managing tarnished plant bugs.

Table 4. Tier two analysis of emergency situation (pre –introduction of sulfoxaflor) compared to non-emergency (post introduction of sulfoxaflor) for tarnished plant bug in Louisiana cotton.

Year	Yield/Acre[1]	TPB + Application Cost[2]	Price ($) /Year	Revenue	Gross Revenue
Prior to introduction of sulfoxaflor					
2008	576.00	$41.63	$0.52	$299.52	$257.89
2009	745.00	$48.26	$0.63	$469.35	$448.09
2010	842.00	$48.61	$0.81	$682.02	$633.41
2011	846.00	$55.52	$0.93	$786.78	$731.26
Averages	**752.25**	**$48.51**	**$0.72**	**$559.42**	**$517.66**
Post introduction of sulfoxaflor					
2012	1020.00	$58.52	$0.69	$703.80	$645.28
2013	1223.00	$42.00	$0.78	$953.94	$911.94
2014	1154.00	$64.00	$0.59	$680.86	$616.86
2015	814.00	$64.00	$0.62	$504.68	$440.68
Averages	**1052.75**	**$57.13**	**$0.67**	**$710.82**	**$653.69**
Percent change (pre-sulfoxaflor vs. post sulfoxaflor)					
	+39.95%	**-17.76%**	**-7.46%**	**+27.06%**	**+26.27%**

[1]USDA National Agricultural Statistics Service, http://www.nass.usda.gov/Statistics_by_State/Louisiana/
[2]Cotton Insect Losses, http://entomology.msstate.edu/resourcs/cottoncrop.asp

REFERENCES USED TO SUPPORT STATEMENTS INCLUDED IN THE DOCUMENT

Adams, A., J. Gore, D. Cook, and A. Catchot. 2012. Insect Control in Mississippi with Transform, pp. 1061-1066. In Proc. 2012 Beltwide Cotton Confer. National Cotton Council, Memphis, TN.

Babcock, J. M, C. B. Gerwick, J. X. Huang, M. R. Loso, G. E. Nakamura, S. P. Nolting, R. B. Rogers, T. C. Sparks, J. D. Thomas, G. B. Watson and Y. Zhu. 2010. Biological Characterization of Sulfoxaflor, a Novel Insecticide. Pest Mgmt. Sci. 67(3):328–334.

Copes, J. T., G. L. Snodgrass, J. Sharp, B. R. Leonard, D. R. Ring, and D. Blouin. 2010. Acephate resistance is widespread in Louisiana tarnished plant bug populations. La. Agric. 53: 14-15.

Emfinger, K., N. Jones, S. Williams and D. Kerns. 2014. Evaluation of selected on tarnished plant bugs in cotton, 2013. Arthro. Man. Tests Vol. 39.

Fontenot, K. A. 2006. Effects of insecticide applications on the distribution of tarnished plant bugs within cotton plants. Louis. State Univ. Dept. of Entomol. Thesis. 51 pp.

Lindsay, J., D. Kerns, S. Brown and S. Williams. 2014. Efficacy of aphicides on cotton aphids, Aphis gossypii, and their natural enemies. In Proceedings of the Beltwide Cotton Conferences, New Orleans, LA, January 6-8, 2014, 851-856.

Lorenz, G, T. Barber, S. D. Stewart, A. Catchot, J. Gore and D. Cook. 2009. Evolving pest management in cotton, p. 1395. In 2009 Proc. Beltwide Cotton Conf.. National Cotton Council, Memphis, TN.

Luckmann W. H. and R. L. Metcalf. 1982. Why pest management, pp. 1-33? In R. Metcalf and W. Luckmann eds. Introduction to Pest Management. John Wiley and Sons, New York, NY.

Moore, J. L., J. H. Temple, J. T. Hardke, K. Emfinger, P. P. Price, J. T. Copes, J. W. Sharpe, E. Burris and K. A. Fontenot, pp. 817-819. In 2010 Proc. Beltwide Cotton Conf. National Cotton Council, Memphis, TN.

Sharp, J. W., J. T. Copes, B. R. Leonard, E. Burris, P. P. Price, J. H. Temple and J. T. Hardke. 2010. Can we rely on any single insecticide for season long tarnished plant bug control in Louisiana cotton, p. 1170. In 2010 Proc. Beltwide Cotton Conferences, National Cotton Council, Memphis, TN.

Snodgrass, G. L. and J. Gore. 2007. Status of insecticide resistance for the tarnished plant bug, pp. 56-59. In 2007 Proc. Beltwide Cotton Res. Conf., National Cotton Council, Memphis, TN.

Snodgrass, G. L., C. A. Abel, R. E. Jackson, and J. Gore. 2008. A Bioassay for Determining Resistance Levels in Tarnished Plant Bug Populations to Neonicotinoid Insecticides. Southwestern Entomologist 33: 173-180.

Willrich-Siebert, M., B. R. Leonard, A. L. Catchot, S. D. Stewart, G. M. Lorenz, and D. R. Cook. 2012a. Field evaluations of sulfoxaflor, a novel insecticide against tarnished plant bug (Hemiptera: Miridae) in cotton. J. Cotton Science 16:129–143 (2012) 129 .http://journal.cotton.org.

Willrich Siebert, M., L.C Walton, R.B. Lassiter, R.A. Haygood, A.T. Ellis, and J.D. Thomas. 2012b. Incorporation of Transform into a Management Program for Tarnished Plant Bug, Lygus lineolaris, in Mid-Southern U.S, pp. 846-851. In 2012 Proc. Beltwide Cotton Res. Conf., National Cotton Council, Memphis, TN.

Zhu, Y., M. R. Loso, G. B. Watson, T. C. Sparks, R. B. Rogers, J. X. Huang, C. B. Gerwick, J. M. Babcock, D. Kelley, V. B. Hegde, B. M. Nugent, J. M. Renga, I. Denholm, K. Gorman, G. DeBoer, J. Hasler, T. Meade, and J. D. Thomas. 2011. Discovery, Biology and Biochemistry of Sulfoxaflor: A Novel Sap-Feeding Insecticide. J. Agric. Food Chem. 59 (7): 2950–2957.